al., on Dec. 24, 2002, incorporated herein by reference. This touch surface can be made arbitrarily large, e.g., the size of a tabletop. In addition, it is possible to project computer generated images on the surface during operation.

[0019] By gestures, we mean moving hands or fingers on or across the touch surface. The gestures can be made by one or more fingers, by closed fists, or open palms, or combinations thereof. The gestures can be performed by one user or multiple simultaneous users. It should be understood that other gestures than the example gestures described herein can be recognized.

[0020] The general operating framework for the touch surface is described in U.S. patent application Ser. No. 10/053,652 "Circular Graphical User Interfaces" filed by Vernier et al., on Jan. 18 2002, incorporated herein by reference. Single finger touches can be reserved for traditional mouse-like operations, e.g., point and click, select, drag, and drop, as described in the Vernier application.

[0021] **FIG. 1** is used to describe the details of operation of the invention. A touch surface **100** includes m rows **101** and n columns **102** of touch sensitive pads **105**, shown enlarged for clarity. The pads are diamond-shaped to facilitate the interconnections. Each pad is in the form of an antenna that couples capacitively to a user when touched, see Dietz above for details. The signal intensity of a single pad can be measured.

[0022] Signal intensities **103** of the coupling can be read independently for each column along the x-axis, and for each row along the y-axis. Touching more pads in a particular row or column increases the signal intensity for that row or column. That is, the measured signal is proportional to the number of pads touched. It is observed that the signal intensity is generally greater in the middle part of a finger touch because of a better coupling. Interestingly, the coupling also improves by applying more pressure, i.e., the intensity of the signal is coarsely related to touching pressure.

[0023] The rows and columns of antennas are read along the x- and y-axis at a fixed rate, e.g., 30 frames/second, and each reading is presented to the software for analysis as a single vector of intensity values (x_0, x_1, . . . , x_m, Y_0, Y_1, . . . , y_n), for each time step. The intensity values are thresholded to discard low intensity signals and noise.

[0024] In **FIG. 1**, the bold line segments indicate the corresponding x and y coordinates of the columns and rows, respectively that have intensities **104** corresponding to touching. In the example shown, two fingers **111-112** touch the surface. The signal intensities of contiguously touched rows of antennas are summed, as are signals of contiguously touched columns. This enables one to determine the number of touches, and an approximate area of each touch. It should be noted that in the prior art, the primary feedback data are x and y coordinates, i.e., a location of a zero dimensional point. In contrast, the primary feedback is a size of an area of a region touched. In addition, a location can be determined for each region, e.g., the center of the region, or the median of the intensities in the region.

[0025] Finger touches are readily distinguishable from a fist, and an open hand. For example, a finger touch has relatively high intensity values concentrated over a small area, while a hand touch generally has lower intensity values spread over a larger area.

[0026] For each frame, the system determines the number of regions. For each region, determine an area and location. The area is determined from an extent (x_{low}, x_{high}, y_{low}, x_{high}) of the corresponding intensity values **104**. This information also indicates where the surface was touched. A total signal intensity is also determined for each region. The total intensity is the sum of the thresholded intensity values for the region. A time is also associated with each frame. Thus, each touched region is described by area, location, intensity, and time. The frame summary is stored in a hash table, using a time-stamp as a hash key. The frame summaries can be retrieved at a later time.

[0027] The frame summaries are used to determine a trajectory of each region. The trajectory is a path along which the region moves. A speed of movement and a rate of change of speed (acceleration) along each trajectory can also be determined from the time-stamps. The trajectories are stored in another hash table.

[0028] As shown in **FIG. 2A**, the frame summaries **201** and trajectories **202** are used to classify gestures and determine operating modes **205**. It should be understood that a large number of different unique gestures are possible. In a simple implementation, the basic gestures are no-touch **210**, one finger **211**, two fingers **212**, multi-finger **213**, one hand **214**, and two hands **215**. These basic gestures are used as the definitions of the start of an operating mode i, where i can have values 0 to 5 (**210-215**).

[0029] For classification, it is assumed that the initial state is no touch, and the gesture is classified when the number of regions and the frame summaries remain relatively constant for a predetermined amount of time. That is, there are no trajectories. This takes care of the situation where not all fingers or hands reach the surface at exactly the same time to indicate a particular gesture. Only when the number of simultaneously touched regions remains the same for a predetermined amount of time is the gesture classified.

[0030] After the system enters a particular mode i after gesture classification as shown in **FIG. 2A**, the same gestures can be reused to perform other operations. As shown in **FIG. 2B**, while in mode i, the frame summaries **201** and trajectories **202** are used to continuously interpret **220** gestures as the fingers and hands are moving and touching across the surface. This interpretation is sensitive to the context of the mode. That is, depending on the current operating mode, the same gesture can generate either a mode change **225** or different mode operations **235**. For example, a two-finger gesture in mode **2** can be interpreted as the desire to annotate a document, see **FIG. 5**, while the same two-finger gesture in mode **3** can be interpreted as controlling the size of a selection box, as shown in **FIG. 8**.

[0031] It should be noted that the touch surface as described here enables a different type of feedback than typical prior art touch and pointing devices. In the prior art, the feedback is typically based on the x and y coordinates of a zero-dimensional point. The feedback is often displayed as a cursor, pointer, or cross. In contrast, the feedback according to the invention can be area based, and in addition pressure or signal intensity based. The feedback can be displayed as the actual area touched, or a bounding perimeter, e.g., circle or rectangle. The feedback also indicates that a particular gesture or operating mode is recognized.

[0032] For example, as shown in **FIG. 3**, the frame summary is used to determine a bounding perimeter **301**